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EXHIBIT

Comparison of Air Cell Tabs

Method

The effectiveness of tabs according to the invention disclosed in US Patent Application No. 10/743,585, assigned to Eveready Battery Company, Inc. (EBC) is compared to tabs disclosed in US 4,649,090 (Oltman), assigned to Rayovac Corporation (ROV).

Because materials were not available from which to make tabs according to Oltman, tabs believed to correspond to those disclosed were taken from commercially available PR70 and PR48 size air cells made by ROV, and these were compared to tabs according to the invention removed from commercially available air cells of the same sizes made by EBC.

Tabs removed from the commercially available ROV PR70 and PR48 size cells were tested to determine loss stiffness and peel strength.

Tabs removed from the commercially available EBC and ROV cells (EBC and ROV tabs, respectively) were used to tab two sizes of mercury-free air cells made by EBC. These cells were tested to determine the open circuit voltages, from which an oxygen transmission rates through the tabs were calculated. From these rates, oxygen permeability values were calculated.

Summary of Results

Loss stiffness of the ROV tabs was found to be about 4,500 N/m, and peel strength ranged from 3.7 to 6.2 psi on the samples tested.

EBC tabs provided an open circuit voltage (OCV) than the ROV tabs for tabbed PR70 and PR48 size cells (thereby reducing the amount of time required to air up to a minimum operating voltage after tab removal). EBC tabs had an average oxygen permeability values of 129 and 52 ($\text{cm}^3 \times \text{m} \times \text{mm Hg}/(\text{m}^2 \times \text{day})$), while the ROV tabs had values of 5 and 8 ($\text{cm}^3 \times \text{m} \times \text{mm Hg}/(\text{m}^2 \times \text{day})$) on PR70 and PR48 cells, respectively.

Experimental Design - Oxygen Permeability

The comparison was done in two button air cell sizes with no added mercury - EBC AC10 (PR70) and AC13 (PR48). The tabs of document (1), document (2) and the present invention were placed on EBC cells of each size, and the cells were tested. Because the only source of document (1) and document (2) tabs was commercially available product, and to insure that all three tab types were handled similarly, all tabs used (including the tabs according to the invention) were removed from other tabbed cells. The experiment setup for each cell type was as follows:

60 EBC mercury-free cells were taken off of their storage tape (tape used instead of tabs between the time cells are assembled and when they are tabbed) and allowed to air up (come to a steady open circuit voltage). These cells were then divided into three lots of twenty cells each.

Packages of commercially available EBC and ROV air cells (sealed with tabs according to the present invention and tabs believed to be according to the Oltman reference) were obtained from local retail stores. Tabbed cells were taken from the packages, and tabs were then removed from 20 of each manufacturer's cells. Tabs were placed on the aired-up mercury-free EBC cells. The tabs were pressed onto the cells with 10 pounds of force to insure that the pressure of application was equal for all cells.

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Lot 1: 20 each PR70 and PR48 size EBC mercury-free cells (as described in US Patent Application No. 10/743,585) taken off storage tape and then tabbed with tabs according to the invention (peel strength: at least 6.5 psi (= 44.8 kN/m²); loss stiffness: 42000 N/m; oxygen permeability: 84.226 (cm³ x m x mmHg)/(m² x day); burst pressure: 47.4 psi (= 0.33 MPa)) that had come from 20 previously tabbed commercially available EBC cells of the same size.

Lot 2: 20 each PR70 and PR48 size EBC mercury-free cells as described for Lot 1, tabbed with tabs that had come from 20 previously tabbed ROV cells of the same size.

Test Results

OCV of Aired-Up Cells before Tabbing

AC 10	AC 13
1.403	1.412

OCV of Cells after Tabbing

AC 10							
Lot	Initial	14 day	20 day	31 day	37 day	44 day	55 day
Lot 1	1.293	1.256	1.250	1.250	1.249	1.257	1.269
Lot 2	1.292	1.213	1.211	1.210	1.212	1.211	1.219

AC 13							
Lot	Initial	14 day	20 day	31 day	37 day	44 day	55 day
Lot 1	1.252	1.211	1.213	1.230	1.238	1.244	1.253
Lot 2	1.253	1.152	1.188	1.206	1.214	1.220	1.229

Calculations

Determine the rate of oxygen transmission through the tab by calculating the change in partial pressure of oxygen inside the cell from the change in measured cell OCV after tabbing.

Equations used:

Nernst Equation: $E = E^{\circ} - (R \cdot T) / (n \cdot F) \cdot \ln(\text{activity of products} / \text{activity of reactants})$;

where: E = Cell Voltage

E° = Standard Potential

R = Gas Constant (8.314 joule/(mol*K))

T = Temperature (K)

F = Faraday's Constant (96485.31 coulombs/mol)

n = number of electrons taking place in reaction (for this reaction 2)

Anode Reaction: $O_2 + 2 Zn \rightarrow 2 ZnO$; where O_2 is a gas and Zn and ZnO are solids

a. Derive equations comparing the initial untabbed cell voltage (E_1) to the cell voltage at intervals after tabbing (E_2) from the Nernst Equation:

$$E_1 = E_1^{\circ} - (R \cdot T) / (n \cdot F) \cdot \ln(\text{activity of products}_1 / \text{activity of reactants}_1)$$

$$E_2 = E_2^{\circ} - (R \cdot T) / (n \cdot F) \cdot \ln(\text{activity of products}_2 / \text{activity of reactants}_2)$$

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- b. Derive an equation for the difference in cell voltages E_1 and E_2 :

$$E_2 - E_1 = (E_2^0 - (R^*T)/(n^*F)^* \ln (\text{activity of products}_2 / \text{activity of reactants}_2)) - (E_1^0 - (R^*T)/(n^*F)^* \ln (\text{activity of products}_1 / \text{activity of reactants}_1))$$

Since the cell cathode reaction is the same, $E_2^0 = E_1^0$ and:

$$(E_2 - E_1)^*(nF/RT) = -\ln (\text{activity of products}_2 / \text{activity of reactants}_2) + \ln (\text{activity of products}_1 / \text{activity of reactants}_1)$$

Because the zinc and the zinc oxide species are solid, the activity of each is 1, and because oxygen is a gas, the partial pressure of the oxygen can be substituted for the activity of oxygen, and:

$$(E_2 - E_1)^*(nF/RT) = -\ln (1/\text{partial pressure of } O_2 \text{ for the cell at } E_2) + \ln (1/\text{partial pressure of } O_2 \text{ for the cell at } E_1)$$

and $(E_2 - E_1)^*(nF/RT) = \ln (\text{partial pressure of } O_2 \text{ for the cell at } E_2 / \text{partial pressure of } O_2 \text{ for the cell at } E_1)$

Because the partial pressure of O_2 for the cell at E_1 is 21%: $\text{ppOxygen}_1 * \exp((E_2 - E_1)^*(nF/RT)) = \text{ppOxygen}_2$

- c. Determine what the partial pressure of oxygen across the tab using the above equation:

% of Oxygen in the atmosphere of the cell for an AC 10							
Lot	Initial	14 day	20 day	31 day	37 day	44 day	55 day
Lot 1	2.01E-3	1.16E-4	7.43E-5	7.15E-5	6.83E-5	1.3E-4	3.13E-4
Lot 2	1.86E-3	4.13E-6	3.51E-6	3.29E-6	3.87E-6	3.65E-6	6.81E-6

% of Oxygen in the atmosphere of the cell for an AC 13							
Lot	Initial	14 day	20 day	31 day	37 day	44 day	55 day
Lot 1	1.74E-4	7.02E-6	8.66E-6	3.28E-5	5.83E-5	9.03E-5	1.89E-4
Lot 2	1.81E-4	7.65E-7	1.24E-6	7.9E-6	9.21E-6	1.48E-5	2.98E-5

- d. Based on c. above, calculate the average oxygen ingress rates for ≥ 14 days:

	AC 10 (liters/day)	AC 13 (liters/day)
Lot 1	8.59×10^{-3}	4.75×10^{-3}
Lot 2	3.57×10^{-6}	7.53×10^{-6}

- e. From the results in d. above, calculate the oxygen permeability values:

	AC 10 ($\text{cm}^3 \times \text{m} \times \text{mmHg} / (\text{m}^2 \times \text{day})$)	AC 13 ($\text{cm}^3 \times \text{m} \times \text{mmHg} / (\text{m}^2 \times \text{day})$)
Lot 1	129	52
Lot 2	5	8